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GSE FOR BALLOON-BORNE IMS: DECOMMUTATOR AND D/A UNITS

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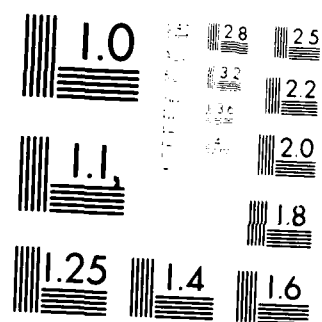
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GSE FOR BALLOON-BORNE I.M.S.:
DECOMMUTATOR AND D/A UNITS

Raimundas Sukys
J. Spencer Rochefort

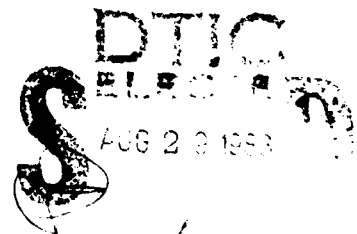
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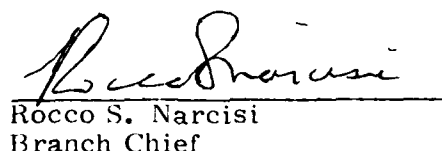
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and/or 8 bit words. Communications interface for commands and messages to and from the airborne instrumentation was also provided. The second unit converted the digital data, supplied by the computer, into analog signals for display and recording. An IEEE-488 compatible interface was used for data transfer.

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TABLE OF CONTENTS

	Page
INTRODUCTION	1
I. DECOMMUTATOR.	3
A. Operation	3
B. Program	7
C. Circuits.	9
II. D/A UNIT.	12
III. APPENDIX - BBIMS-2 DECOM SUBROUTINES.	19
IV. REFERENCES.	45
V. PERSONNEL	45
VI. RELATED CONTRACTS AND PUBLICATION	46

TABLE OF ILLUSTRATIONS

Figure No.

1. BLOCK DIAGRAM OF GROUND SUPPORT SYSTEM.	16
2. BBIMS-2 GSE DECOM	17
3. BBIMS-2 GSE D/A UNIT.	18

1. Title

2. Author

3. Date

4. Classification

5. Page

6. Total Pages

7. Distribution/Availability Codes

8. Remarks

TABLE OF SELECTED ACRONYMS AND ABBREVIATIONS

1. ATN. ATTENTION
2. CMOS COMPLIMENTARY METAL OXIDE SEMICONDUCTOR
3. CPU. CENTRAL PROCESSING UNIT
4. CRT. CATHODE RAY TUBE
5. CS CHIP SELECT
6. D/A. DIGITAL TO ANALOG
7. DAV. DATA VALID
8. D to A DIGITAL TO ANALOG
9. EOI. END OR IDENTIFY
10. EPROM. ELECTRICALLY PROGRAMMABLE READ ONLY MEMORY
11. FIFO FIRST IN, FIRST OUT
12. HEXFET POWER METAL OXIDE SEMICONDUCTOR (Trade name of
International Rectifier)
13. IFC. INTERFACE CLEAR
14. LED. LIGHT EMITTING DIODE
15. LSB. LEAST SIGNIFICANT BIT
16. μ P MICROPROCESSOR
17. NDAC NOT DATA ACCEPTED
18. NRFD NOT READY FOR DATA
19. PCM. PULSE-CODE MODULATION
20. RAM. RANDOM ACCESS MEMORY
21. RTS. REQUEST TO SEND DATA
22. SRQ. SERVICE REQUEST
23. TTL. TRANSISTOR-TRANSISTOR LOGIC
24. USART. UNIVERSAL SYNCHRONOUS/ASYNCHRONOUS RECEIVER/
TRANSMITTER

INTRODUCTION

Two ground based units were developed to support a Hewlett Packard HP9845C system in data processing operations during the flight of a Balloon Borne Ion Mass Spectrometer (BBIMS). One of the support units was designated to decommutate the incoming PCM data, while the other was developed to convert digital data, supplied by the computer, into analog signals for display.

The data gathering modes of the mass spectrometer could be controlled from the ground. The instrument could be commanded to execute any one of a number of programs or entire repertoires of programs stored on board. Also, entirely new programs could be transmitted from the ground for execution over a serial command link available for this purpose. Commands and instructions are sent to the mass spectrometer control unit through a command transmitter. A single 8 bit word within the PCM data train was used as the down link for communications from the airborne unit. Detailed description of the BBIMS instrumentation and its capabilities can be found in References 1, 2 and 3. The flexibility of the airborne instrument allowed the ground based scientist to tailor the data gathering process to the existing conditions. This required an almost real time processing and display of data, and the capability to send commands to and to receive communications from the airborne mass spectrometer control unit. Also, a large number of signals were displayed to monitor the status and the performance of the balloon borne instrumentation.

During the first successful flight of the BBIMS instrumentation package in May 1982, the HP9845C system was used to display the monitor

signals and to plot selected portions of the ion spectrum. It received the data from a ground control unit designed primarily to communicate with the airborne control unit. The data was available in a parallel form, one byte at a time, together with a word synchronization pulse. Frame synchronization was not available; therefore, the computer had, for all practical purposes, to decommutate the data. This task consumed a considerable amount of processing time. Commands to the mass spectrometer had to be sent through the ground control unit.

The newly developed system overcomes many of the disadvantages of the earlier ones and is shown in the block diagram of Figure 1.

The decommutator, one of the newly constructed ground support units, relieved the HP9845C system from the task of the PCM data decommutation. It presented the selected data, at the convenience of the computer, through the IEEE-488 bus.⁴ Also, it provided a communications interface between the computer and the serial command link and relayed the messages from the balloon-borne mass spectrometer control unit, within the PCM data stream, to the HP computer. Provisions were included for the use of a printer to obtain a hard copy of all communications.

The D/A UNIT was designed to convert eight bytes of data into analog signals. Microammeters and output terminals were provided for the display and for the recording of the analog data. The data channels were selected by the computer.

This report describes the capabilities and the operation of these two support units. Detailed descriptions of the circuits are provided.

I. DECOMMUTATOR

The primary task of the BBIMS-2 Decommutator Unit was, as its name implies, to decommutate the incoming PCM data from the balloon borne instruments. The decommutated data was made available to the user through an IEEE-488 interface bus and also in a parallel form as 16 and/or 8 bit words. The parallel data was accompanied by appropriate synchronization pulses. The secondary task of the unit was to provide communications/command interface to the airborne mass spectrometer control unit. All communications passing through the interface were available at yet another port for use by a printer or a CRT terminal. The communications ports were compatible with the RS-232-C⁵ link. LED indicators were provided to monitor the operation of the decommutator unit.

A. OPERATION

The incoming PCM data from the balloon borne instruments was formatted into a 20 word frame transmitted at 12 kilobits per second. Eight bit words were used. A 16 bit pattern (EB90H) provided the frame synchronization. The subframe consisted of 96 data words. Two of the subframe words appeared in each frame. Those words were preceded by a subframe identification code. Most of the other words within the frame carried data associated with the quadrupole ion mass spectrometer, while the subframe was mostly used for monitor data or for the data from supporting experiments. A notable exception were two words within the frame. One contained the ONE's count of the frame, but did not include the frame synchronization pattern nor the ONE's in the count word itself. The count was intended to

show the number of non-canceling errors within the frame and, therefore, provided a rough indication of the quality of the telemetry link. The other word carried communications from the mass spectrometer flight control unit to the ground station. The communications words were inserted into the PCM data stream at an equivalent rate of 300 baud. This rate was chosen to accommodate the relatively slow ground support equipment. Also, since the data gathering rate of the quadrupole ion mass spectrometer was quite low, not every frame of the PCM pulse stream carried new and/or valid data. The first word of a frame was used to indicate the status of the data and the presence or absence of a new communications word within that frame. The decommutation process was controlled, to a large extent, by the status of two bits within that word.

Whenever the designated bit (MSB) in the first frame word indicated that a new and valid data was present in the frame, the data was extracted and stored. Only selected words were thus processed. The selection was determined by software. Primarily, the words directly associated with the data gathered by the ion mass spectrometer were chosen.

Eight 32 word registers were created for storage of that data in the 1K RAM included in the decommutator circuits. Each of the registers was dedicated to one minor frame. Thus eight minor frames of data could be stored consecutively before the very first frame of data was lost due to an overwrite. Although only 13 words needed storage locations, the registers were purposely extended to 32 locations. The balloon borne PCM encoder format was software programmable; therefore, future flights can utilize a different format if many more

words within a frame require storage in the RAM. To maintain this flexibility the very first location of each storage register was reserved for the number of words actually stored; therefore, only the locations used for storage were addressed during the transfer of the data to the peripheral processing equipment. Once the data was read, ZEROS were placed into the first location of the storage register indicating that the register has been processed.

Subframe data, which contained mostly the monitor signal of the airborne instrumentation was extracted and stored continuously. For that purpose two 256 byte registers were allocated in the RAM. Once again, the registers were able to accommodate considerably more data than was available in each subframe; therefore, future subframes may contain more data. The subframe data words were stored consecutively. Once all of the subframe words were stored, a binary number representing the number of words contained in the register was placed into the first location. During the following major frame of the PCM data the second storage register was filled. By that time, hopefully, the data from the first storage register were transferred to the peripheral sources. If not, then an overwrite occurred. The decommutation process was controlled by the subframe identification word which had to precede the first subframe word within a minor frame. A subframe identification word 00H was interpreted as a beginning of the subframe.

The data stored in the RAM was available only through the IEEE-488 interface. A subroutine searched for a full storage register containing the mass spectrometer data. Once found, the decommutator established contact with the bus controller and then transmitted the

stored data. When transfer was completed, the program returned to check if the next consecutive register containing the mass spectrometer data was full. Thus the data transmission was carried out on FIFO basis. Only when all eight of the frame storage data registers were empty, the contents of a full subframe data storage register were output. Therefore, the mass spectrometer data had a priority over the subframe data. To differentiate between the two data types, an identification code, six for the subframe data, seven for the minor frame data, was transmitted as the first word. The word count stored in the first location of the storage register was not transmitted. The end of the data transfer was marked by a TRUE state on the EOI line during the transmission of the last data word. Provisions were included to continue data transmission from the same storage register following an interruption by IFC command from the controller. When the frame synchronization was lost the data processing was suspended.

The parallel data was available in real time. It remained stable for the duration of approximately one PCM data word. The 16 bit words were presented with the odd numbered PCM data word as the most significant byte. A word sync pulse lasting one-half of the duration of a PCM word and centered in that time period marked the availability of the 16 bit word. The byte wide data was also marked with a similar pulse on a different output line. Finally, when the whole synchronization word (16 bits) was available at the parallel data port, a synchronization pulse coinciding with and of the same duration as the second frame synchronization byte (90H) appeared on the third output line. The parallel data, although its integrity could be questionable, was available even when the frame synchronization was lost.

The communications from the airborne mass spectrometer control unit to the ground station were processed in somewhat similar manner as the PCM data. When a selected bit (3rd. USB) in the first word of the PCM data train indicated that a new communications word was present in the frame, that word was extracted and stored. A 256 byte register was allocated in the RAM for that purpose. Next, the status of the decommutator USART, used to retransmit the communications from the flight control unit to the xontroller (HP9845C), was checked. When it was found to be empty, the previously stored word or, if none were available, the very recent word was transferred into the USART. When no new communications were present in the frame, then only the USART was serviced during the time interval allocated for the communications word within the frame.

B. PROGRAM

The program controlling the operations of the decommutator unit could be subdivided into three groups of subroutines each performing distinct tasks. The system was prepared for operation by the initialization routines. Data transfer and handshakes with the bus controller were handled by another set of subroutines. The decommutation and storage process was controlled by a subprogram designed to accommodate the frame format. This latter program called upon appropriate subroutines to perform the necessary decommutation and storage tasks. The decommutation subprogram was entered from the data transfer subroutines upon an interrupt generated by the hardware. Most of the time the system operated in the data transfer group of subroutines.

Upon TURN-ON or RESET the program initialized the decommutator ports, established clock frequency and continued into a subroutine

which determined the polarity of the incoming PCM data. Signal conditioning circuits were set to present the data in the proper polarity to the decommutator shift registers. Initial frame synchronization was also established at this point. From there, the system entered a routine where a search was conducted for a full decommutated data storage register. When a full register was found, another routine requested service from the controller of the IEEE-488 bus. After the designation to be a TALKER (code 29D) has been received, another subroutine transferred data from the storage register to the bus. When the transfer of the data from that register has been completed the system returned to the routine which searched for another full storage register.

The tasks of the data transfer from the storage registers in the RAM to the bus were interrupted whenever a PCM data word was ready for processing. Upon interruption, the contents of all CPU registers were saved. The control was transferred to the decommutator subprogram which selected an appropriate subroutine to process that particular word within the PCM data frame. To adapt the decommutator to a different PCM data format only the decommutator subprogram had to be changed. The subprogram consisted mainly of a series of jump instructions transferring control to the various processing routines. Upon completion of a given task, the program restored the contents of the CPU registers and returned to continue the interrupted data transfer process. The subroutines of the program and their flow graphs are presented in the APPENDIX at the end of this report.

C. CIRCUITS

The decommutator design was based on the 8085 μ P and its family of support components. Some of the support functions were delegated to a sequential logic utilizing CMOS components. The circuit diagram is shown in Figure 2.

The incoming PCM data was transmitted through U20, U25 and the AND-AND-OR gate arrangement (U27) to a 16 bit shift register (U10, U11). These gates were used to invert the PCM data when necessary. Once the program determined, during the initialization process, that an inversion of polarity was required, a negative level was applied to pin 2 of U27 through the port C of U4. This process was non-reversible unless the system was reinitialized.

The clock to enter the data into the serial-in-parallel-out shift register (U15, U16) was derived from the CPU clock through U4 and U24. Synchronization with the incoming PCM data was maintained by resetting U24 through the AND-AND-OR gates (U26) on every transition in the data bit stream (transitions marked by pulses generated by U25) or by utilizing the external clock supplied with the PCM data. When present, the external clock was delayed one quarter of a period by U18 and its period was doubled by U19. After passage through U26 the transitions of this signal caused U25 to generate pulses which were then used to synchronize the internal clock with the incoming data.

The switchover from the data controlled synchronization to the external clock synchronization was accomplished in the gates of U26 in conjunction with the signals generated by U18. This monostable

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The switchover from the data controlled synchronization to the external clock synchronization was accomplished in the gates of U26 in conjunction with the signals generated by U18. This monostable

detected the presence of the external clock, generated the switchover signals and lit a LED to indicate to the user that indeed the external clock was present.

The frequency of the data shift clock output of U24 was divided by 8 in the bit counter of U28. The output of the counter was used to interrupt the μP and to latch the data present in the shift register into the parallel data output ports U15 and U16. The synchronization pulses for the user of the parallel data were derived in units 29 and 30 from the signals of U28.

The overall synchronization between the PCM data and the sequential logic circuits was maintained by software. At the beginning of the subroutine which processed the second byte of the frame synchronization word (90H) a pulse from the LSB of port C of U4 reset the bit counter U28. From there on, provided the data and/or the external clock did not have noise induced transitions, the system was synchronized. When the synchronization was lost, it was readily restored when the CPU again detected the PCM frame synchronization word. During the time that the CPU searched for the frame synchronization pattern, additional reset pulses were generated whenever the byte EBH was detected. These pulses were necessary to resynchronize the bit counter in order that the second byte (90H) of the synchronization word could be detected eight bits later. Therefore, the BYTE, the WORD and the FRAME synchronization pulses for the parallel data output were not valid during the search periods.

A LED was used to signal the synchronization status. In absence of signal the light was off. Random signals with an occasional frame synchronization byte pattern produced a flickering light. Synchronization was marked by a steady glow.

Upon receiving an interrupt from the bit counter (U28), the CPU transferred the data byte from the shift register U11 through port A of U5 into the scratch pad RAM of U4. From there, only selected data words were transferred into one of the storage registers in the 1k byte RAM U14.

The communications from the balloon borne ion mass spectrometer control unit to the ground control were transmitted through the USART U17 and the SR-232C interface circuits U21 and U22. When ready to transmit, the USART generated a Request To Send signal ($\overline{\text{RTS}}$). When the request was granted ($\overline{\text{CTS}}$ low), transmission of the messages started (via P1-2) and continued until all of the stored messages were transmitted. The transmission could be interrupted by canceling the permission to send ($\overline{\text{CTS}}$ high). The USART resumed transmission of the interrupted message when the $\overline{\text{CTS}}$ signal was once again received. The end of transmission was indicated when the USART removed the $\overline{\text{RTS}}$ signal from the line. Although the software to receive data through the USART from the command link receiver was not included in the program, hardware connections to the USART were provided for that purpose.

Commands from the ground based control to the mass spectrometer flight control unit arriving on P1-2, were transmitted to the command transmitter via S2-14. The decommutator unit acted as a junction box between the two units and provided an isolated connection to the printer port. The output of the USART was OR'ed with the command signals before entering the port.

The IEEE-488 bus transactions were carried out through U4 and U5. U4 received the signals from the bus which U5 transmitted to

the bus. Port A of U4 monitored the data bus. Port B of the same unit handled the handshakes and the commands. Data transmission took place through port B of U5 in conjunction with the buffers U13. The handshakes were transmitted through port C of U5 and the buffers U12.

Port C of U4 was designated as a general utility port. The synchronization pulse for the bit counter and the signal to control the polarity of the incoming PCM data were transmitted through this port. Also, LED indicators to display the status of the decommutator unit were controlled through that port.

The DAV LED was turned on when the data within the PCM data frame was new and valid. The TTY LED was lit when a communications word was present in the frame. The SR LED indicated that a service request (SRQ) was issued to the controller by the decommutator unit. Finally, the TALK LED turned on when the decommutator started data transmission over the IEEE-488 bus. These LED's were under software control and were turned on for a minimum of 3 PCM data frames.

The chip enable functions were generated by the decoder U2, while U9 latched the low byte of the address for the EPROM U8, where the decommutator program was stored.

II. D/A UNIT

To observe the data and/or the monitor signals received from the balloon-borne instrumentation an eight channel digital to analog converter unit was constructed. It was designed to be compatible with the IEEE-488 bus.

Its task was to receive an eight bit digital data word from the bus controller, to perform digital to analog conversion and to display the resulting analog signal on a designated microammeter. Each of the analog signals was also available on two output connectors for recording devices.

The D to A converter unit was designed to be a listener only. It could be addressed with the decimal codes 22 or 30 followed by one of the secondary codes 16 through 23. The secondary codes designated one of the eight D to A converters to be used for the conversion and the display of the digital data word.

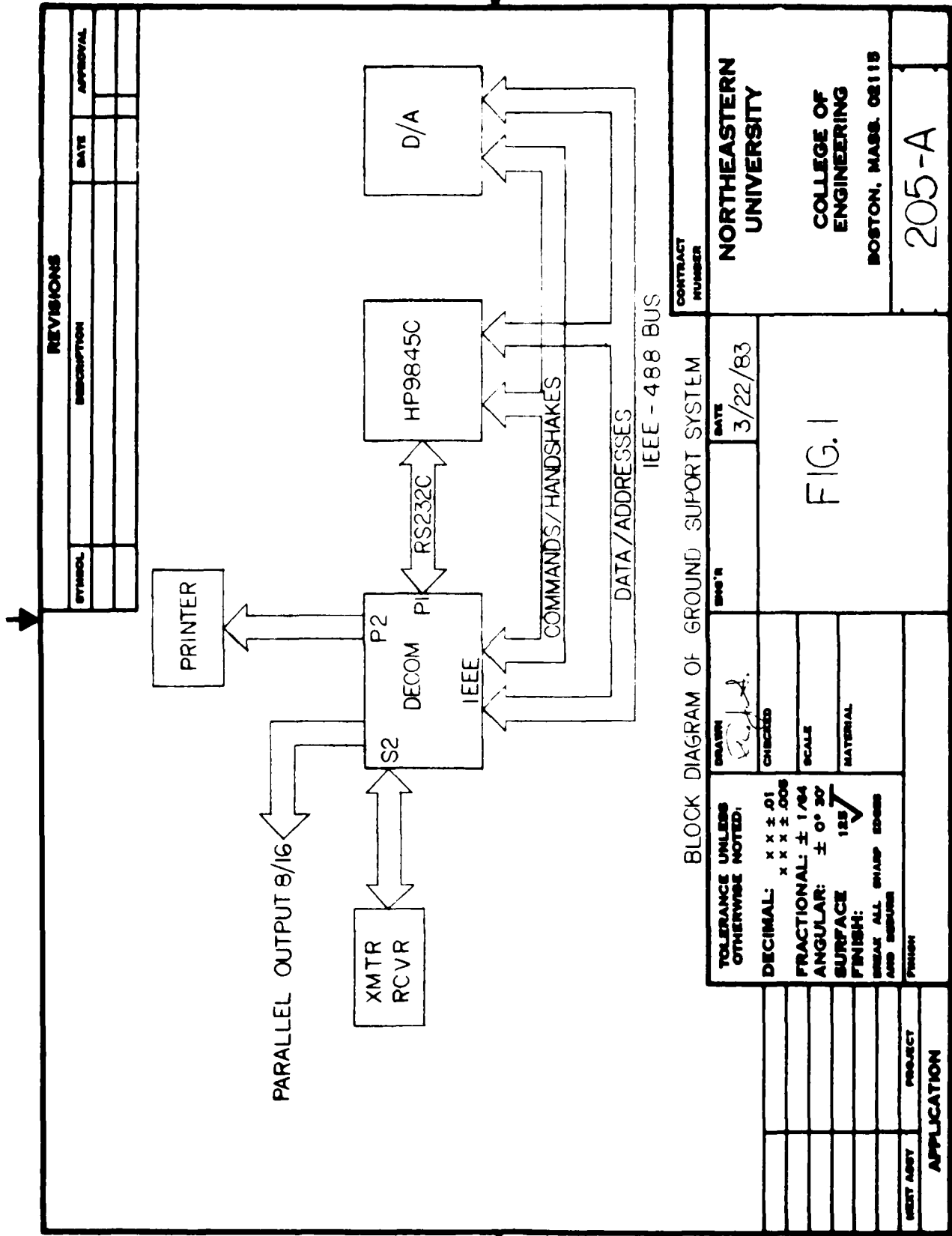
The circuit diagram for the D/A unit is shown in Figure 2. With the exception of the circuits directly interfacing with the IEEE-488 bus, standard CMOS devices were used to implement the necessary control logic. A TTL compatible high speed CMOS unit (U10) transmitted the data bus signals to the internal bus. Low power Schottky TTL gates (U1A,B) received the control signals and the low power HEXFETS (U2A,B) were used to perform the handshakes. To translate from the TTL levels of the IEEE-488 bus related devices to the CMOS levels, pull-up resistor network (U11) was used. The inverters (U3A,B) and the gates (U9) detected the presence of the primary select code on the internal bus. If at the same time the ATN line was in the TRUE state, the output of U9B enabled the gate U7A. A transition of the DAV line to the TRUE state produced a positive pulse at the output Q2 of the monostable U5A, which through the gate U7A SET the flip-flop U6A. Thus the primary select code was detected and the gates U8 were set to receive the secondary select code. When one of the eight secondary codes appeared on the internal bus, gates U8 became enabled. Next,

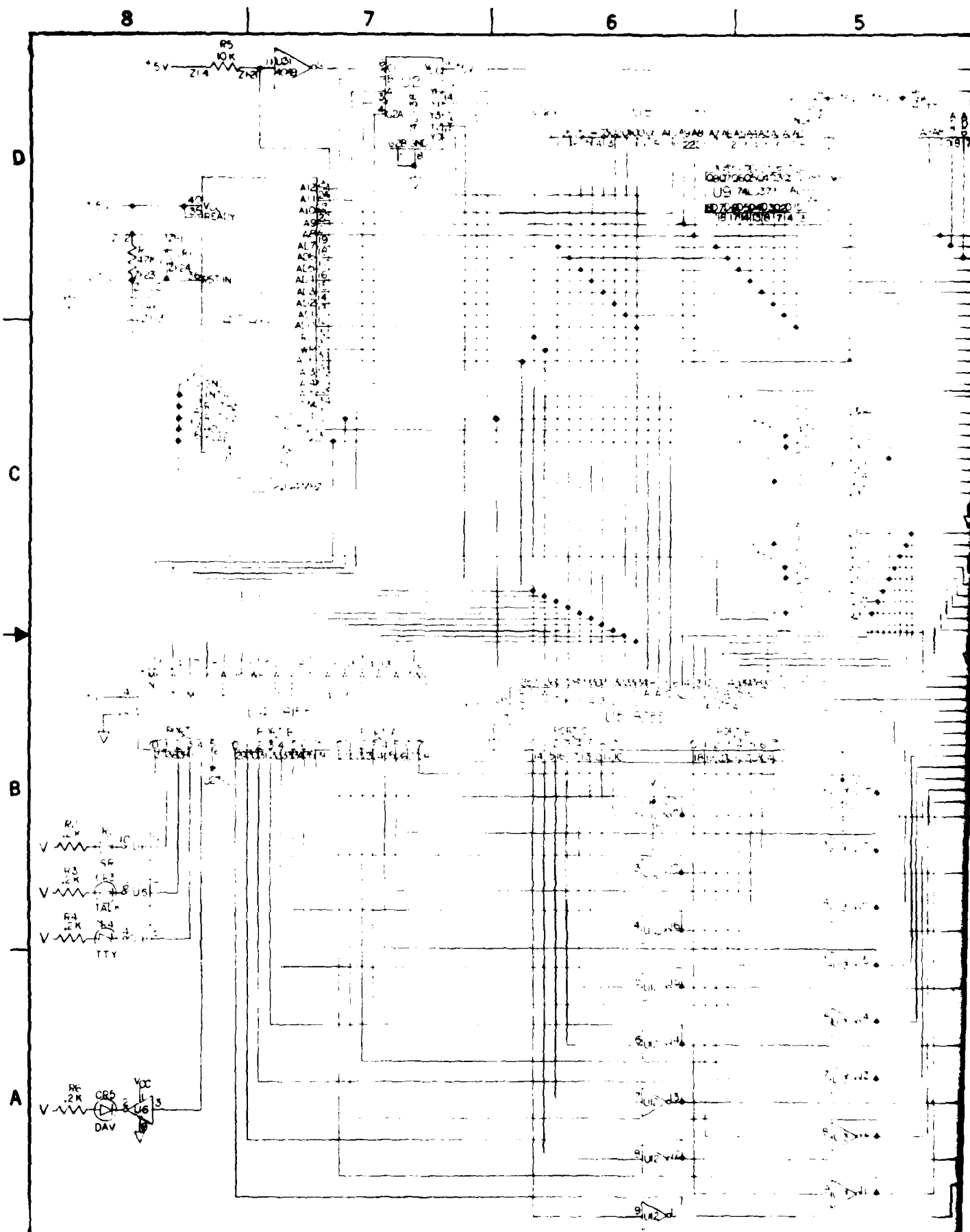
when the DAV line made the transition into the TRUE state, the four least significant bits of that code were latched into U12 by a pulse from U5A passing through the gate U8B. At the same time U4A was SET. Output Q_2 of U4A enabled the gate U7B. When the ATN line returned to the FALSE state, signifying that the next byte on the bus was data, the output of U12 was enabled. The ATN signal was passed through U1A, U3C, U7B and U3E. Thus one of the D to A converters (U13-U20) was selected (\overline{CS} low) by U12 responding to the previously latched secondary code. The digital data word present at that time on the internal bus was latched into the internal register of the selected D to A converter by a pulse originating from \overline{Q}_2 of U5A. Once again that pulse was generated by the transition of the DAV signal from FALSE into the TRUE state. Since latching occurred on the trailing edge of the pulse, setting time for the data and the set-up time for the converter was provided.

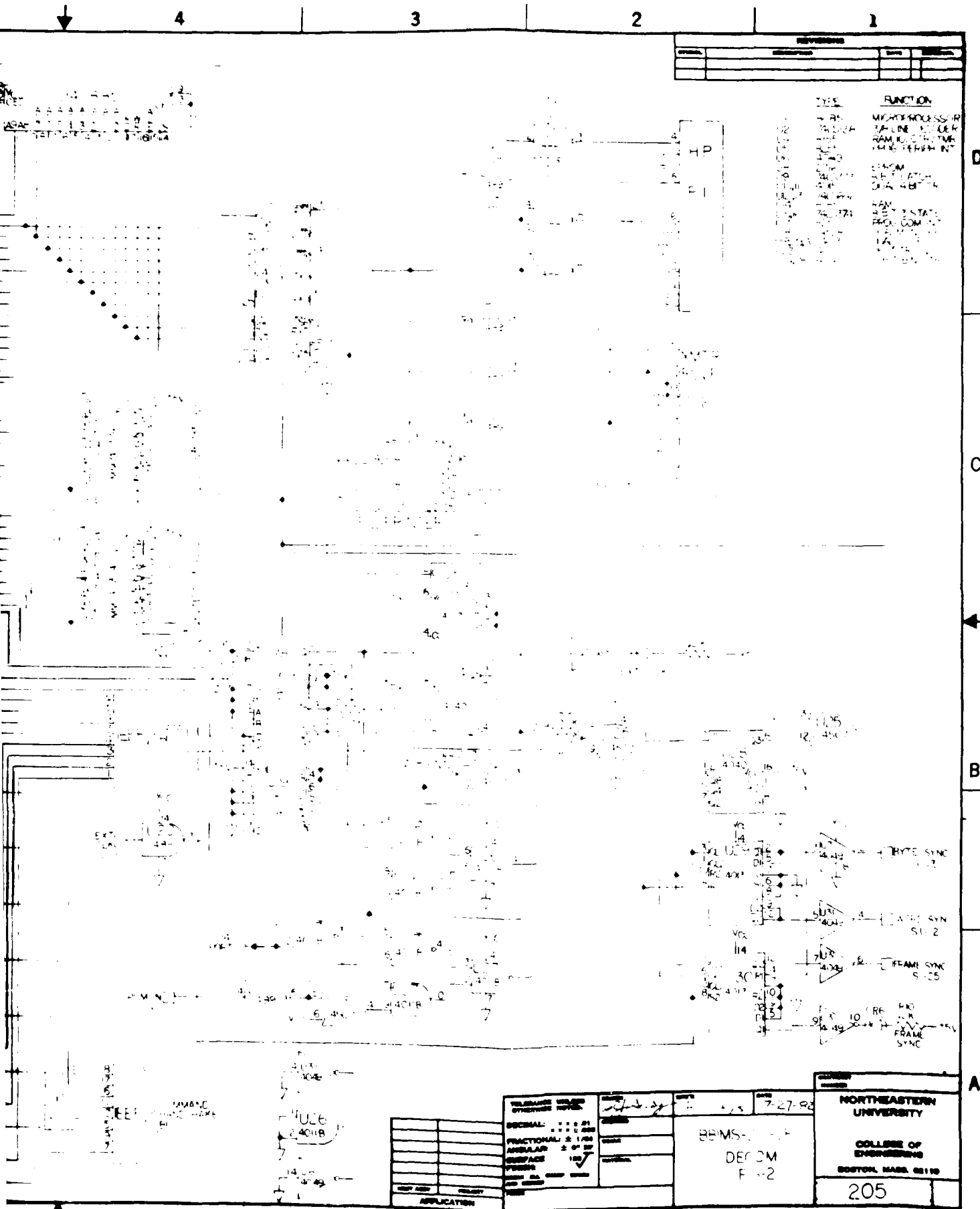
To indicate to the user of the unit, that data transfer into the D to A converter had taken place, the LED CR3 was lit whenever the outputs of the U12 were enabled. Flip-flop U6B generated the pulse to turn the LED on.

FALSE state on the ATN line disabled the code selection gates. Transitions of the DAV line from TRUE to the FALSE state with the ATN line in the FALSE state prepared the secondary code detection circuits for the next select code. The transitions generated pulses at U5B. These pulses passing through U7C clocked the flip-flops U6A and U4A into the reset states. The secondary selection code detection gates U8A became disabled. Also, the output of U12 returned to the ONE state. Thus the A to D converters were deselected.

The handshake signals were generated by U4B. A pulse from \overline{Q}_2 of U5A produced the NRFD and \overline{NDAC} outputs. A pulse from \overline{Q}_1 of U5B at the trailing edge of the DAV signal returned the handshake lines to \overline{NRFD} and NDAC states. Initialization pulse for the control circuits at power turn-on was generated by U3D.







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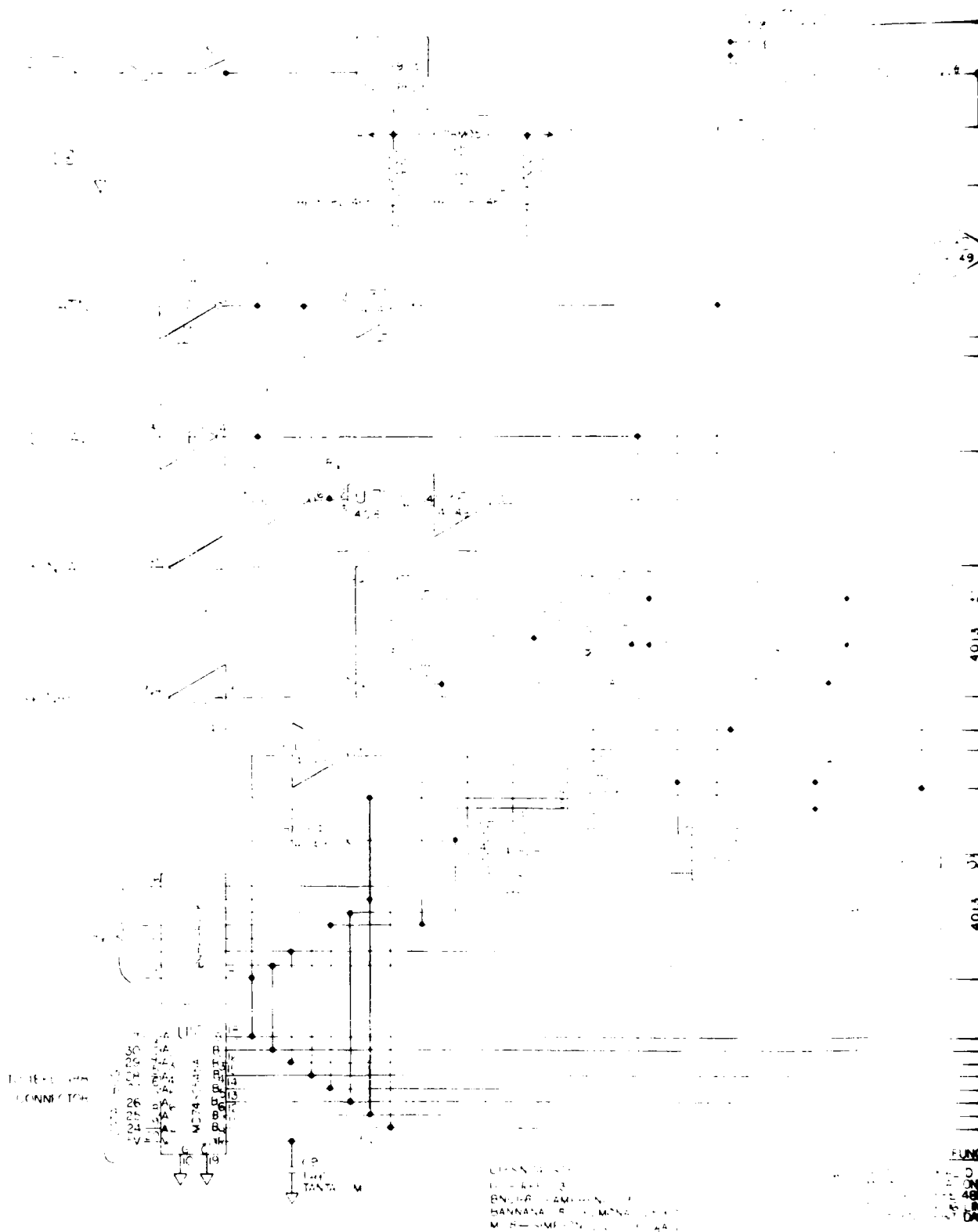
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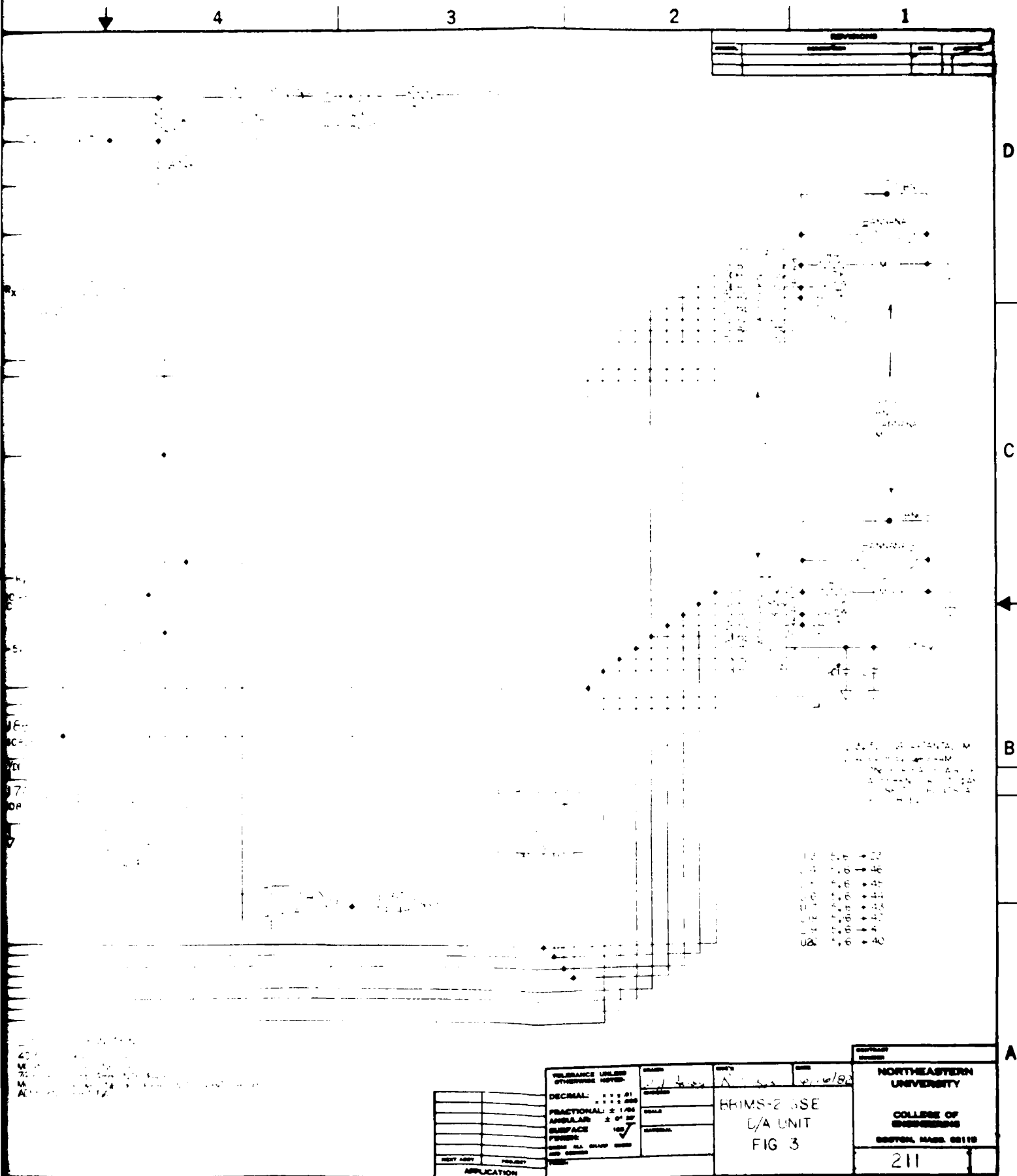
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 ENGINEERING MATERIALS
 HANDBOOK
 M. H. - 5000

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- 15
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APPENDIX - BBIMS-2 DECOM SUBROUTINES

TABLE OF CONTENTS

	<u>DESCRIPTION PAGE</u>	<u>FLOW CHART PAGE</u>	<u>CODE PAGE</u>
1. XFR	20	22	36
2. DCM	20	22	34
3. BK	20	22	36
4. WRD	20	22	37
5. WRD 1	20	23	36
6. TTY	20	23	37
7. SFID	20	24	41
8. SFWRD	21	24	41
9. FSI	21	25	41
10. FS2	21	27	43
11. SEARCH	21	28	40
12. IDLE	21	29	38
13. E488	21	30	39
14. OUTPUT	21	32	37
15. IFC	21	22	38

DECOMMUTATOR SUBROUTINES

XFR

This subroutine is entered upon the RST 7.5 interrupt. It transfers the present PCM data word into a temporary storage. The contents of all registers are saved in the stack. The appropriate address for the DCM routine is established and then transferred into the program counter.

DCM

This routine controls the decommutation by calling upon appropriate subroutines to process the words of the PCM data frame. To accommodate other PCM data frame formats the routine must be changed.

BK

The registers are reloaded from the stack. Interrupts are enabled and the system is returned to the interrupted task. This routine is entered at the end of every subroutine called by DCM.

WRD

When valid data is present in the PCM data frame, a selected word is stored in the buffer RAM. The storage locations within the buffer and the stored word counter are controlled by the routine.

WRD 1

This routine determines if new data and/or communications from the BBIMS flight control unit are present in the PCM data frame. It sets appropriate flags (DV and TTY) and lights the monitor LED's.

TTY

Communications from the BBIMS flight controller are stored into a temporary buffer within the RAM. When USART is empty a stored character is transferred into the USART for transmission to the computer.

SFID

When the subframe identification word is a binary ZERO, the contents of the subframe word counter are transferred into the first location of the subframe buffer. Pointers for the new storage buffer and the full buffer to be read out are established.

SFWD

This routine stores the subframe words and keeps count of the number of words stored.

FS1

Checks for the first frame sync word. If the word is not found it sets an error flag. When DV flag is detected the routine closes the present minor frame storage buffer by placing the stored word count into the first buffer location. New storage buffer address and pointer are established. In the case that the new storage buffer is in the process of being read out, the read pointer is pushed to the next buffer. Also the turn-offs of the monitor LED's are controlled by this routine.

FS2

Outputs synchronization pulse to the PCM data bit counter. Checks for the second frame sync word and re-establishes frame sync when necessary.

SEARCH

On turn-on or reset the search routine is entered as a part of an initialization process. It establishes the polarity of the incoming PCM data and the original frame sync for the decom system. From SEARCH the program enters IDLE.

IDLE

In this routine the system searches for full storage buffers. The minor frame data buffers have the priority. Only when all of these are empty the subframe data buffers are checked.

E488

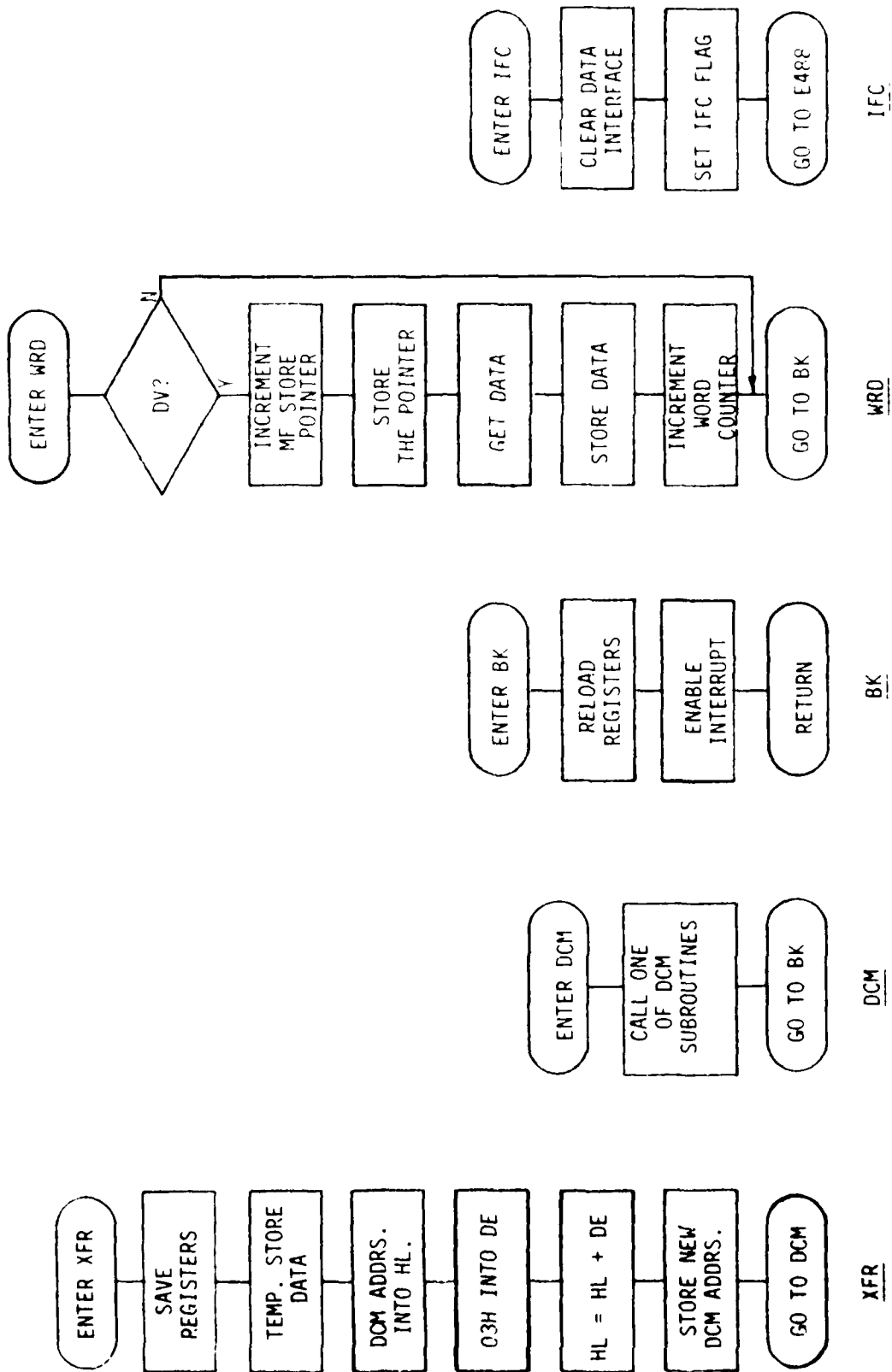
This routine requests service and establishes the first contact with the computer before data transmission. Parallel polling ID method is used.

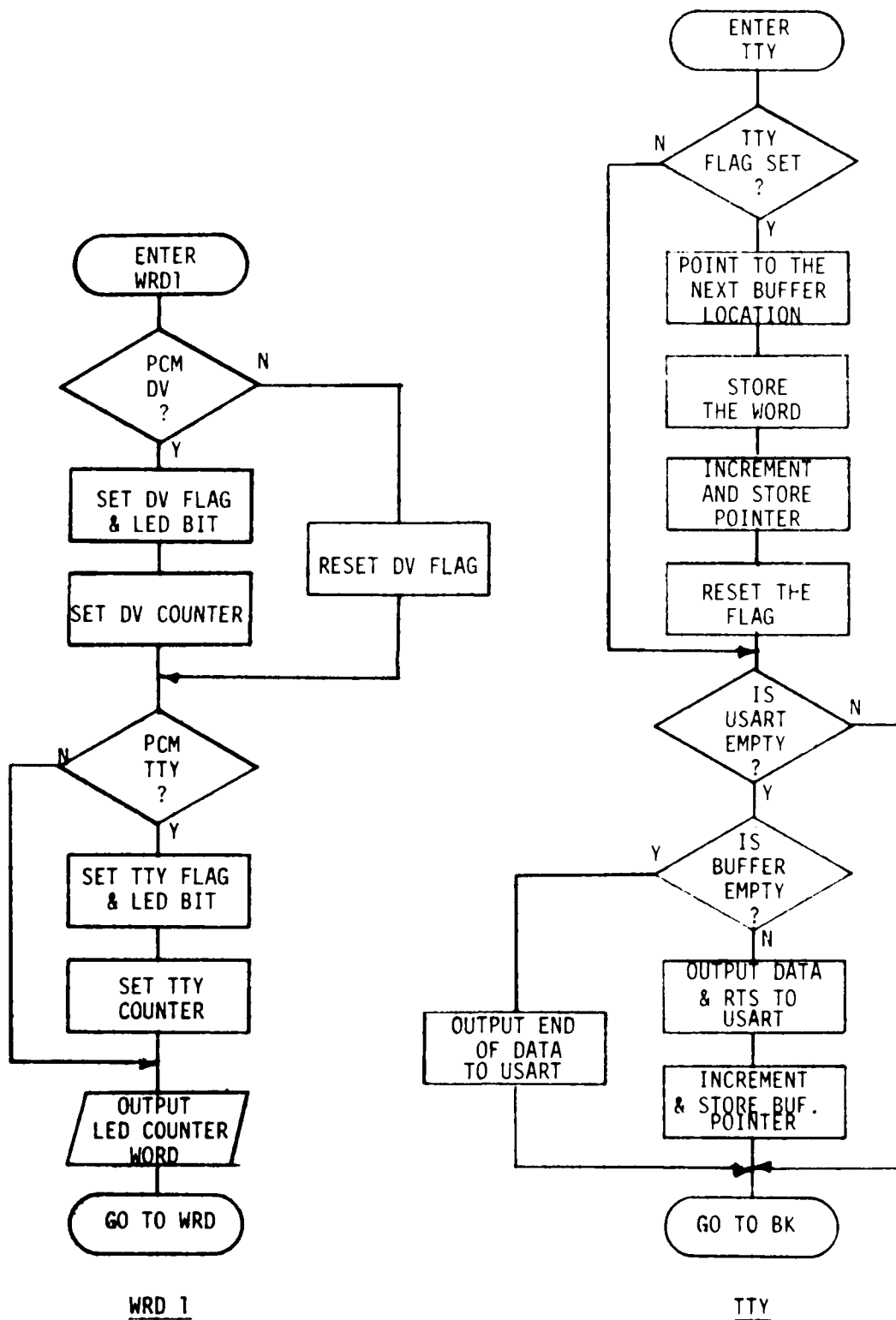
OUTPUT

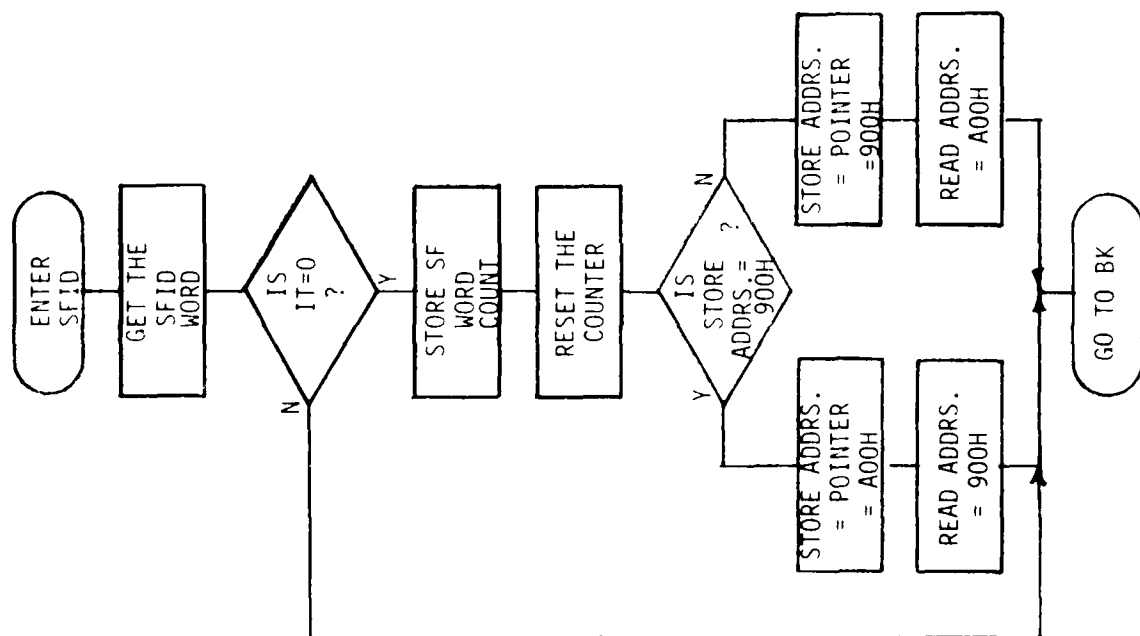
Performs the necessary handshakes and transfers data from the storage buffers of the decom to the computer. The first data word identifies the data as coming from a subframe or a minor frame buffer. Data transfer ends with the EOI control code.

IFC

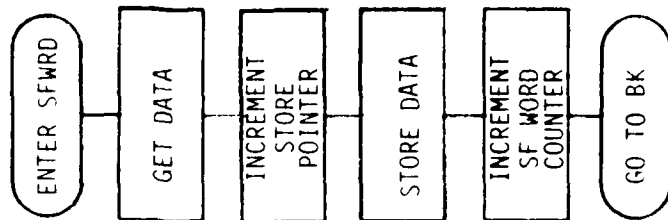
Clears the data interface upon detection of the IFC command during the data transmission. E488 is entered from this routine.



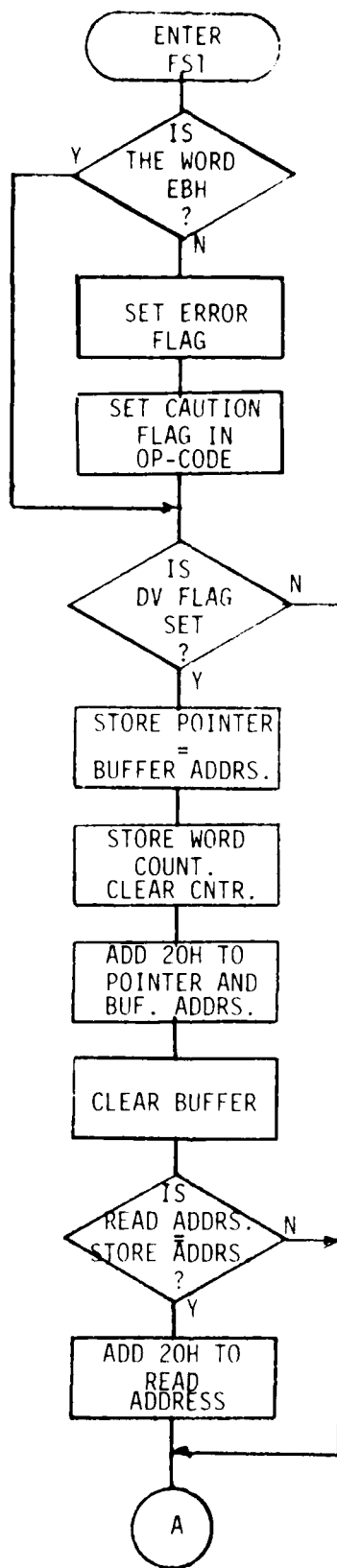




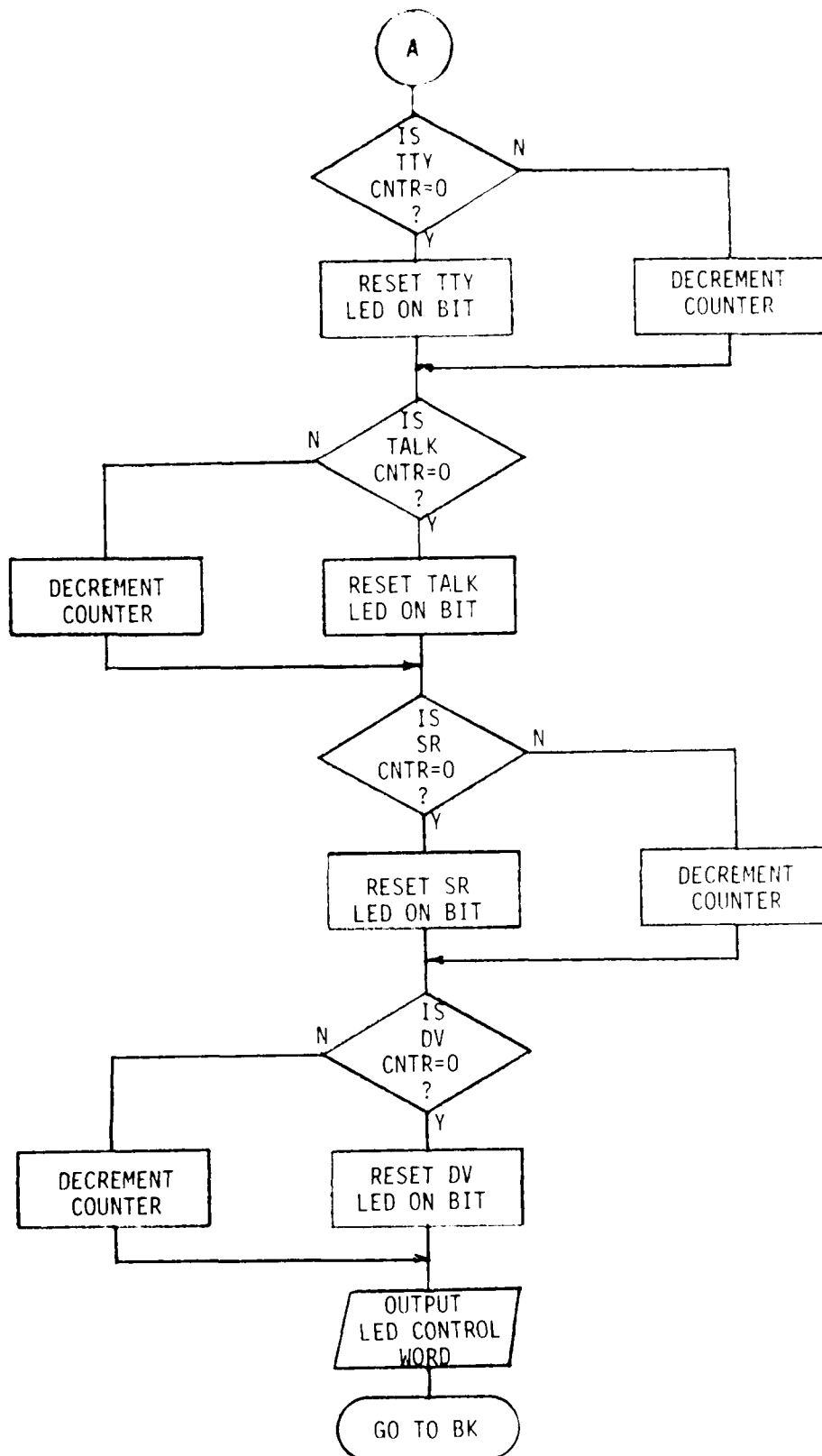
SFID



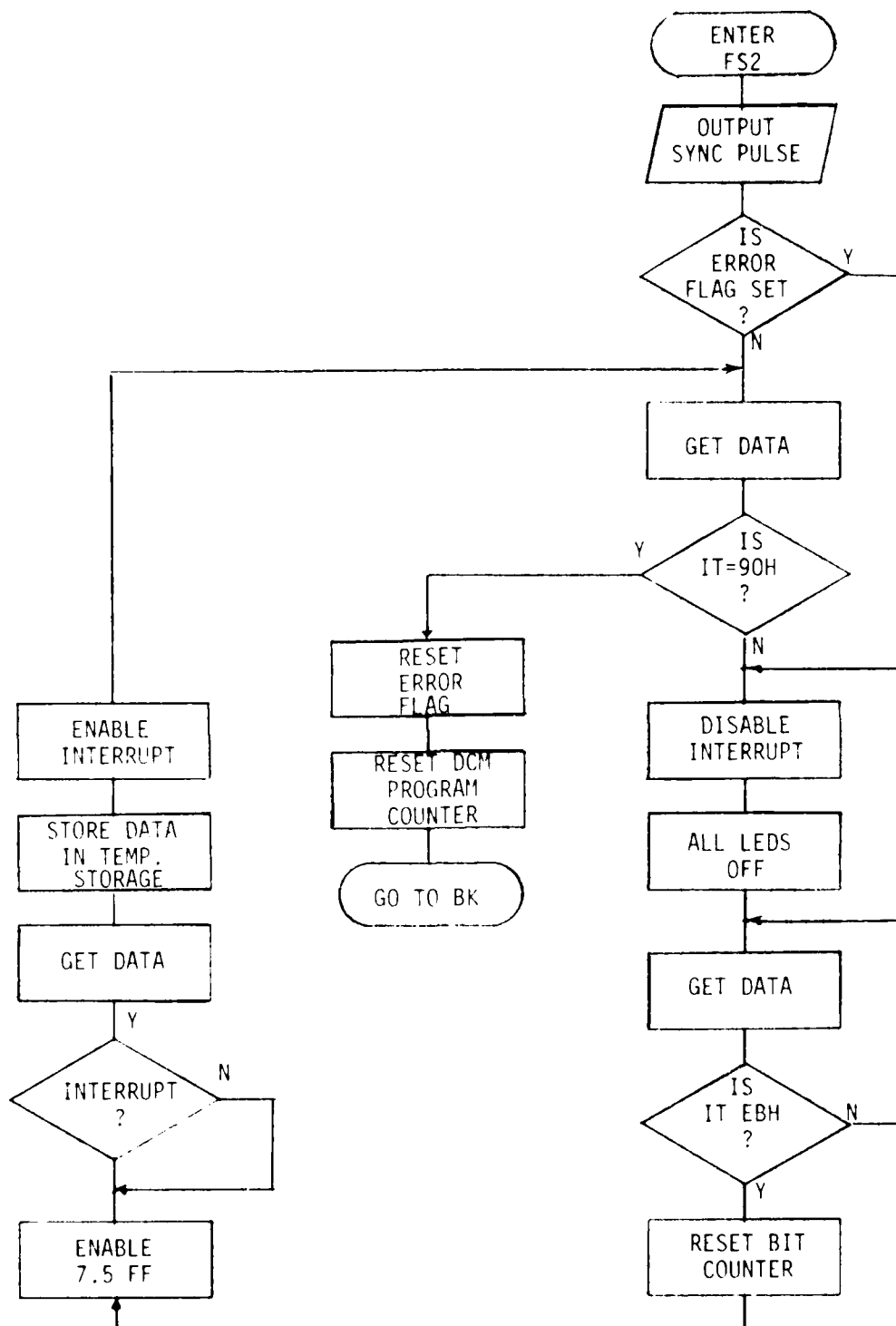
SFWRD



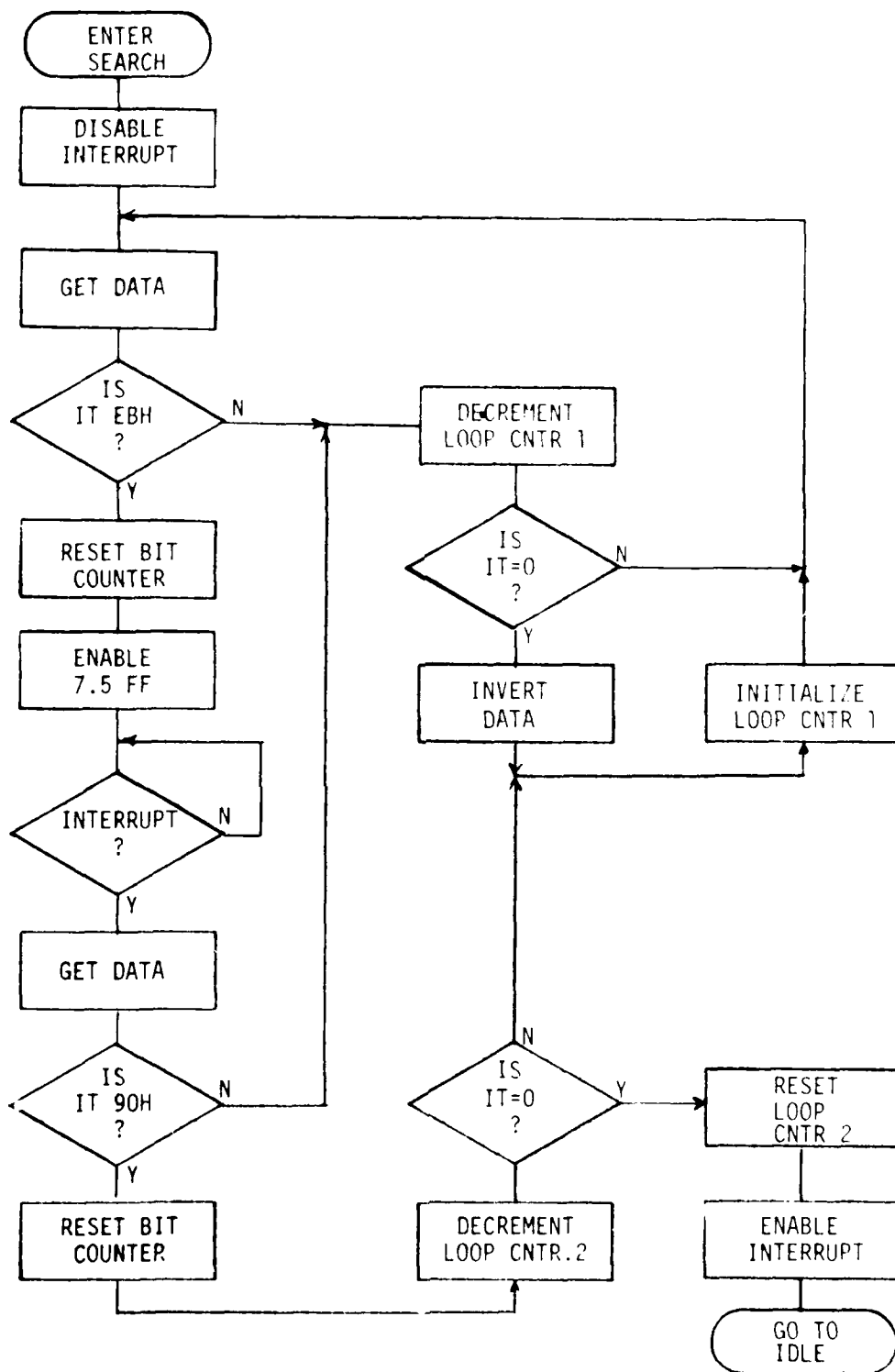
FS1



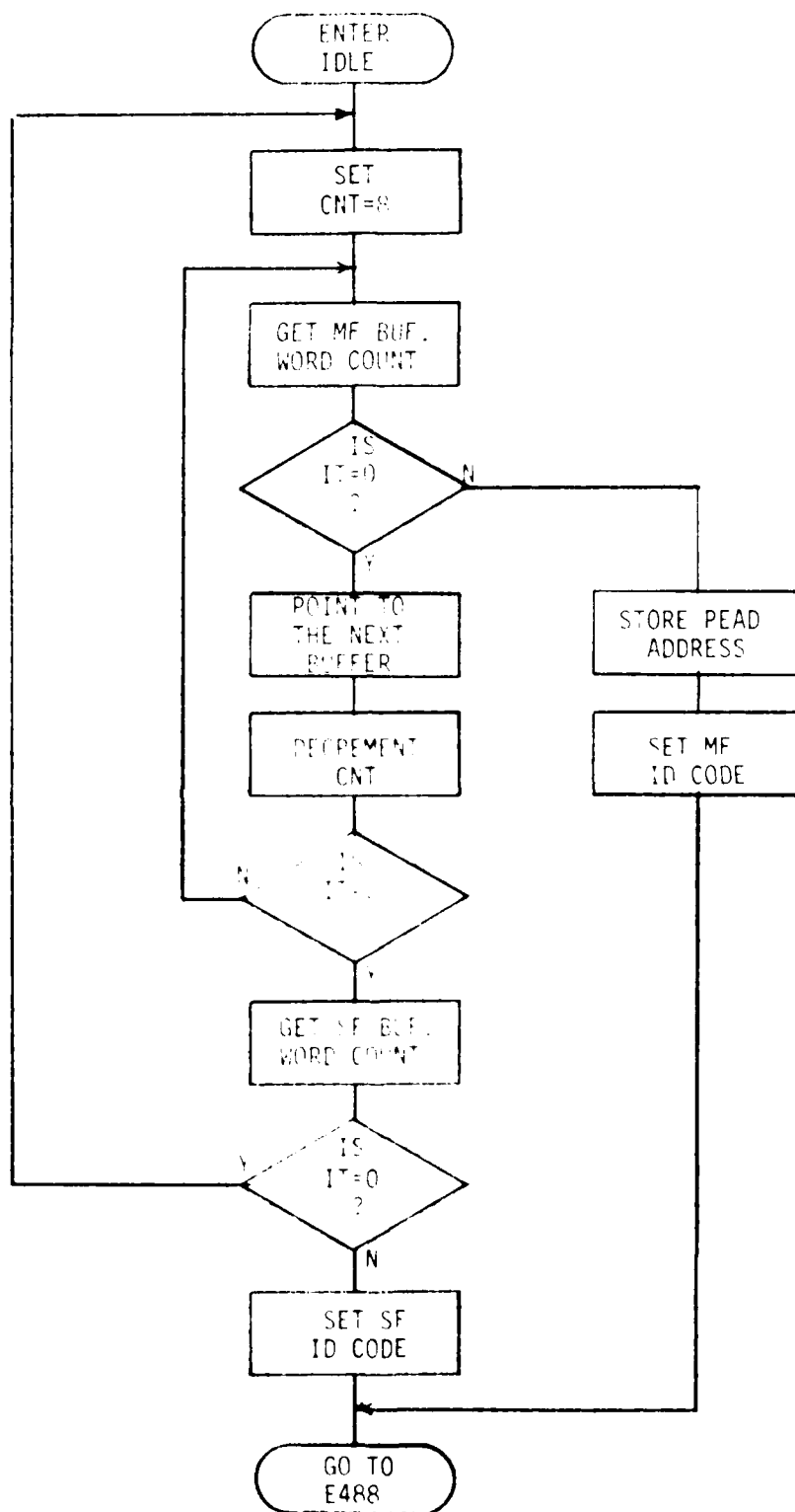
FS1 (CONT.)



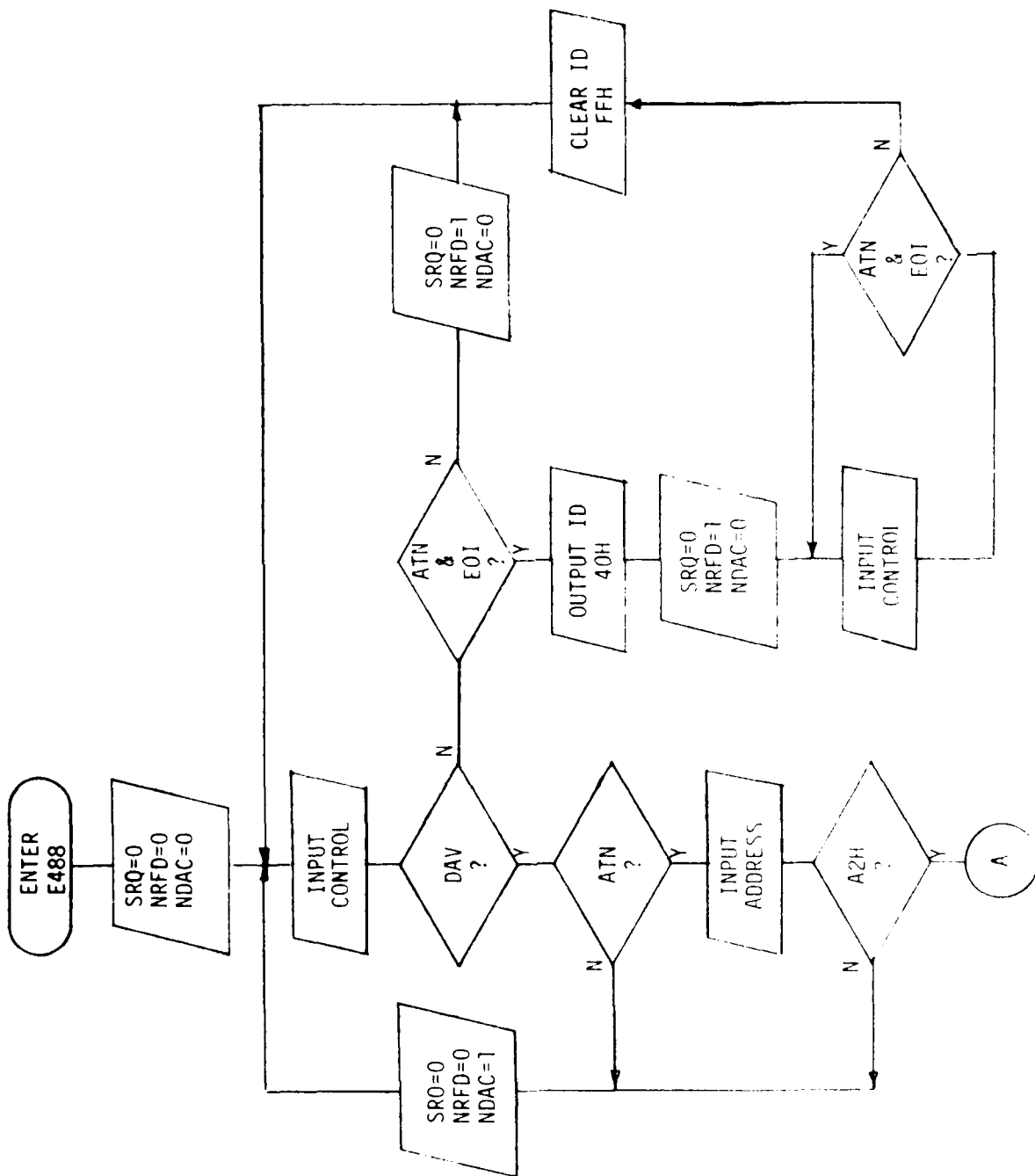
FS2



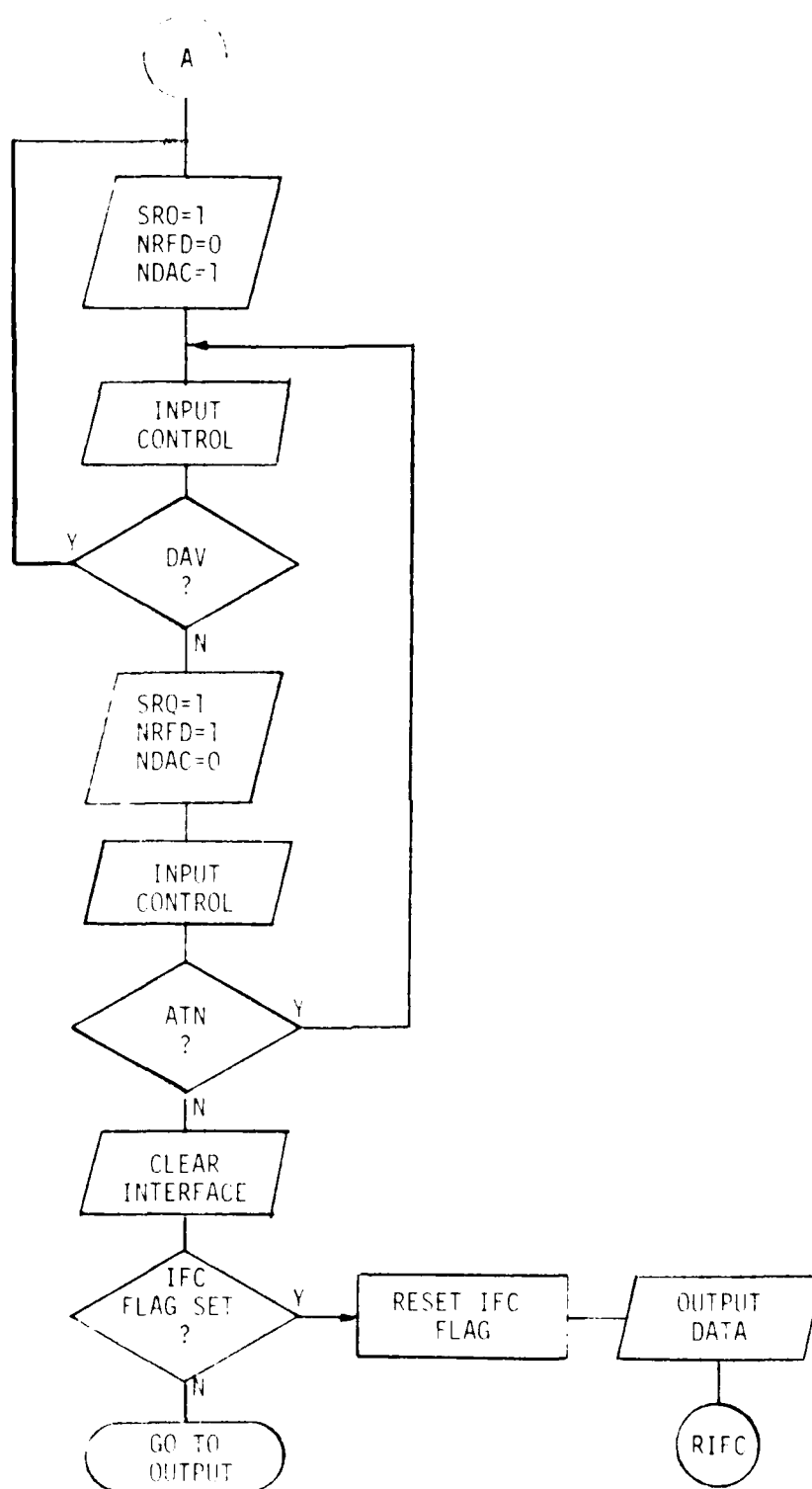
SEARCH



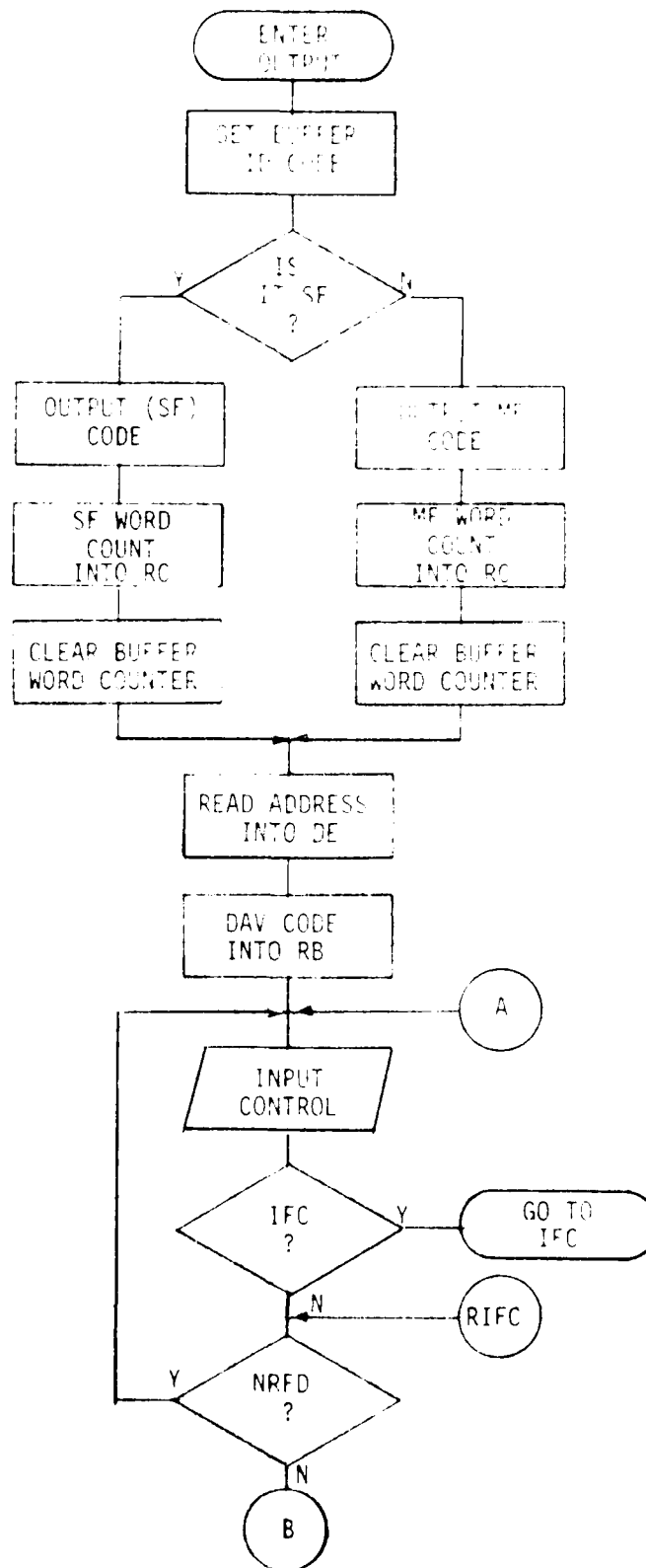
IDLE



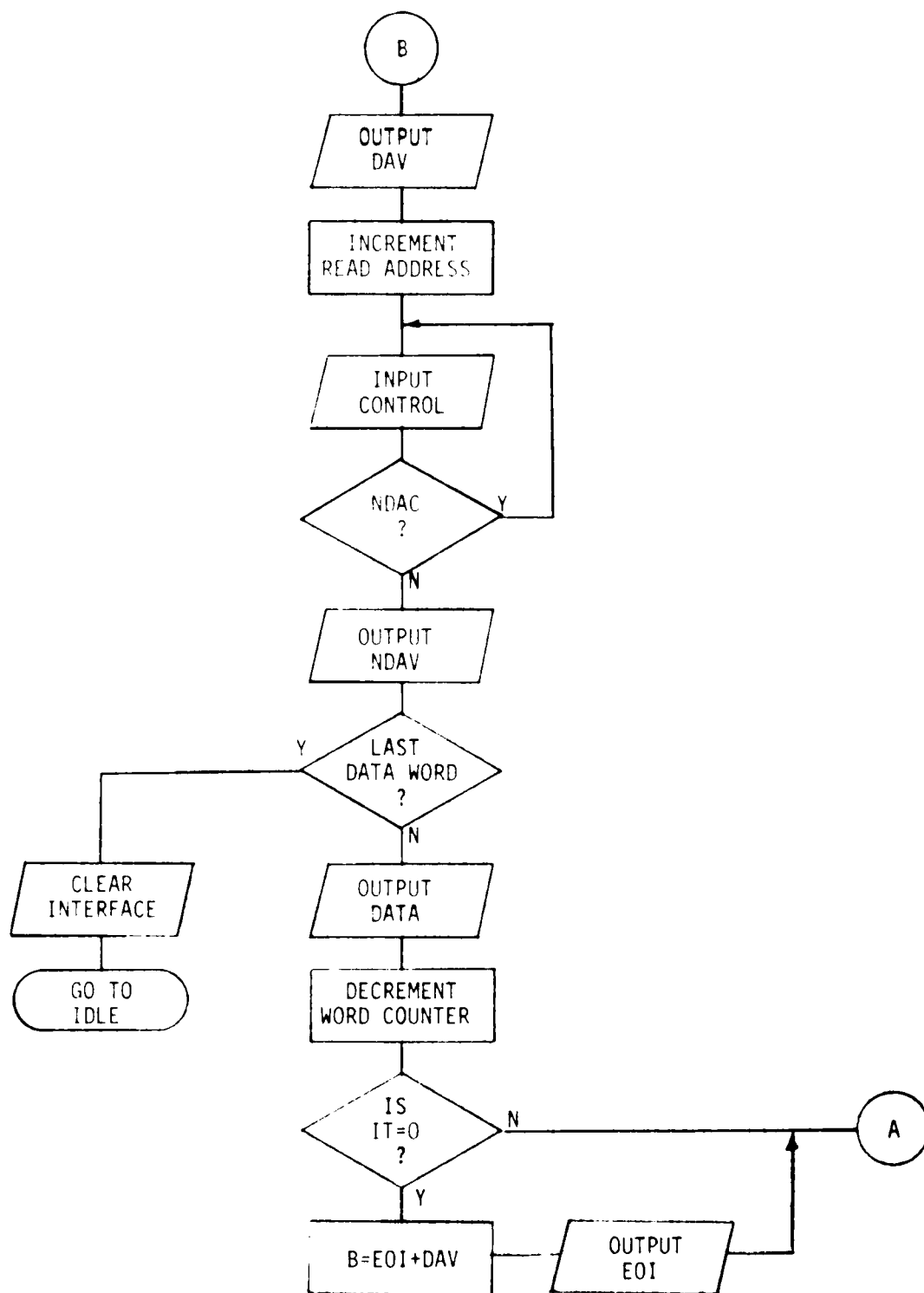
E488



E488 CONT.



OUTPUT



OUTPUT CONT.

Task/Project	Category	Assigned To	Status	Progress (%)	Notes
Project A	Development	John Doe	In Progress	75%	Implementing new feature X.
Project B		Jane Smith	Completed	100%	All tests passed successfully.
Project C		Mike Johnson	On Hold	20%	Awaiting client feedback.
Project D		Alice Brown	Planned	0%	Scheduled for next week.
Project E		Bob White	In Progress	50%	Writing user manual.
Project F		Charlie Green	Open	10%	Investigating bug report.
Project G		Diana Prince	Completed	100%	Campaign launched.
Project H		Frank Miller	In Progress	60%	Reviewing budget.
Project I		Grace Wilson	Open	30%	Recruiting for new role.
Project J		Henry Black	Completed	100%	Contract signed.
Project K	Operations	Ivy Red	In Progress	40%	Optimizing workflow.
Project L		Jack Blue	Open	15%	Server upgrade.
Project M		Karen Yellow	Completed	100%	Vulnerability scan.
Project N		Liam Purple	In Progress	55%	Preparing audit.
Project O		Mia Silver	Open	25%	Conducting QA.
Project P		Noah Gold	Completed	100%	Feedback survey.
Project Q		Olivia Bronze	In Progress	70%	Prototype ready.
Project R		Peter Platinum	Open	10%	Supplier selection.
Project S		Quinn Nickel	Completed	100%	Route optimization.
Project T		Rachel Copper	In Progress	65%	System integration.
Project U	Marketing	Sam Tin	Open	5%	Vendor selection.
Project V		Tina Lead	Completed	100%	Impact assessment.
Project W		Umar Silver	In Progress	45%	Green building cert.
Project X		Victoria Gold	Open	12%	Event planning.
Project Y		Walter Bronze	Completed	100%	Partnership signed.
Project Z		Xavier Platinum	In Progress	80%	Patent application.
Project AA		Yara Nickel	Open	35%	Survey distribution.
Project AB		Zoe Copper	Completed	100%	Report completed.
Project AC		Adam Silver	In Progress	60%	Brand guidelines.
Project AD		Alex Bronze	Open	18%	Media outreach.
Project AE	Finance	Aria Platinum	Completed	100%	Event successful.
Project AF		Ben Nickel	In Progress	50%	Partnership talks.
Project AG		Bella Copper	Open	22%	Loyalty program.
Project AH		Brian Silver	Completed	100%	Launch event.
Project AI		Brianna Gold	In Progress	70%	Process improvement.
Project AJ		Bryce Bronze	Open	10%	Network expansion.
Project AK		Brynn Platinum	Completed	100%	System upgrade.
Project AL		Bryson Nickel	In Progress	40%	Renovation work.
Project AM		Brynn Copper	Open	5%	Impact study.
Project AN		Brynn Silver	Completed	100%	Green initiative.
Project AO	HR	Brynn Gold	In Progress	60%	Community meeting.
Project AP		Brynn Bronze	Open	15%	Partnership plan.
Project AQ		Brynn Platinum	Completed	100%	Feedback loop.
Project AR		Brynn Nickel	In Progress	75%	Innovation pipeline.
Project AS		Brynn Copper	Open	12%	Resilience plan.
Project AT		Brynn Silver	Completed	100%	Efficiency report.
Project AU		Brynn Gold	In Progress	55%	Accuracy audit.
Project AV		Brynn Bronze	Open	8%	Safety audit.
Project AW		Brynn Platinum	Completed	100%	Compliance check.
Project AX		Brynn Nickel	In Progress	45%	Report draft.
Project AY	Customer Service	Brynn Copper	Open	10%	Relations plan.
Project AZ		Brynn Silver	Completed	100%	Partnership review.
Project BA		Brynn Gold	In Progress	60%	Training session.
Project BB		Brynn Bronze	Open	15%	Development cycle.
Project BC		Brynn Platinum	Completed	100%	Transparency report.
Project BD		Brynn Nickel	In Progress	50%	Automation pilot.
Project BE		Brynn Copper	Open	20%	Digitization project.
Project BF		Brynn Silver	Completed	100%	Modernization plan.
Project BG		Brynn Gold	In Progress	65%	Stewardship plan.
Project BH		Brynn Bronze	Open	10%	Innovation fund.
Project BI	Community Outreach	Brynn Platinum	Completed	100%	Support program.
Project BJ		Brynn Nickel	In Progress	55%	Growth strategy.
Project BK		Brynn Copper	Open	25%	Loyalty program.
Project BL		Brynn Silver	Completed	100%	Diversification plan.
Project BM		Brynn Gold	In Progress	70%	Integration project.
Project BN		Brynn Bronze	Open	18%	Optimization plan.
Project BO		Brynn Platinum	Completed	100%	System implementation.
Project BP		Brynn Nickel	In Progress	40%	System upgrade.
Project BQ		Brynn Copper	Open	5%	Monitoring system.
Project BR		Brynn Silver	Completed	100%	Reporting system.
Project BS	Partnerships	Brynn Gold	In Progress	60%	Engagement system.
Project BT		Brynn Bronze	Open	15%	Management system.
Project BU		Brynn Platinum	Completed	100%	Service system.
Project BV		Brynn Nickel	In Progress	75%	Development system.
Project BV		Brynn Copper	Open	12%	Supply chain system.
Project BV		Brynn Silver	Completed	100%	Logistics system.
Project BV		Brynn Gold	In Progress	55%	Inventory system.
Project BV		Brynn Bronze	Open	8%	Facilities system.
Project BV		Brynn Platinum	Completed	100%	Environmental system.
Project BV		Brynn Nickel	In Progress	45%	Sustainability system.

35

Let from 8080-8085 ASM V3.3 ITEM

00108	0125	324008	STA	0E10H	
00109	0128	326008	STA	0B20H	
00110	012B	328008	STA	0B30H	
00111	012E	32A008	STA	0B40H	
00112	0131	32C008	STA	0B50H	
00113	0134	32E008	STA	0B60H	
00114	0137	320009	STA	0900H	
00115	013A	32000A	STA	0A00H	
00116	013D	D313	OUT	IOF2	RELEASE FUNCTION COUNTER
00117	013F	D319	OUT	IOF8	RELEASE IF DATA
00118	0141	D31A	OUT	IOF9	RELEASE IF DATA
00119	0143	3E1A	MVI	A+1AH	REMOVE 2.5 INTERRUPT
00120	0145	30	SIM		
00121	0146	FB	FI		
00122	0147	C31D03	JMP	SEARCH	
00123	014A	E5	PUSH	H	SAVE REGISTER CONTENTS
00124	014B	D5	PUSH	D	
00125	014C	E5	PUSH	R	
00126	014D	F5	PUSH	PSW	
00127	014E	DB18	IN	IOF1	FINISH DATA
00128	0150	320310	STA	MA	
00129	0153	2A2010	LMDI	DMFA	LOAD I/O FROM ADDRESS
00130	0156	110300	LXI	D+0003H	PUT 0003 INTO THE DE REGISTER
00131	0159	19	DAD	D	ADD THE DE REGISTER VALUE TO THE NEW I/O ADDRESS
00132	015A	227010	SHLD	DMFA	STORE THE NEW I/O ADDRESS
00133	015D	F9	CHI		GO TO IOE
00134	015E	F1	POP	PSW	RESTORE REGISTERS
00135	015F	E1	POP	R	
00136	0160	D1	POP	D	
00137	0161	F1	POP	H	
00138	0162	FB	FI		
00139	0163	C9	RFI		RETURN TO DATA PROCESSING
00140	0164	3A0310	WDB1	MA	GET I/O WORD FROM TEMP. STORAGE
00141	0167	07	RLC		FIN THIS FRAME
00142	0168	D28001	JNC	W1	
00143	016B	210410	LXI	H+IOE	SET IOE FLAG
00144	016E	3680	MVI	M+ROH	
00145	0170	210810	LXI	H+FAUSE	SET IOE COUNTER
00146	0173	3603	MVI	M+03H	
00147	0175	3A0110	LDA	M2	SET IOE LED ON BIT
00148	0178	F610	ORI	10H	
00149	017A	32011C	STA	M2	STORE CONTROL WORD
00150	017D	C38501	JMP	W2	
00151	0180	210410	W1	LXI	H+IOE
00152	0183	3600	MVI	M+00H	RESET IOE FLAG
00153	0185	3A0310	W2	LDA	MA
00154	0188	0F	RRC		GET I/O WORD
00155	0189	0F	RRC		
00156	018A	0F	RRC		
00157	018B	D2A301	JNC	W3	IF IN THIS FRAME
00158	018E	210510	LXI	H+IEE	IF NOT LED
00159	0191	3680	MVI	M+ROH	SET IEE FLAG
00160	0193	210910	LXI	H+ETIE	SET IEE LED COUNTER

00101 0180 3603	MVI	M+0AH	
00102 0180 360110	LDA	M+	SET ITY ON BIT
00103 0180 1608	ORI	08H	
00104 0180 320110	STA	M2	STORE CONTROL WORD
00105 0180 130601	JMP	W4	
00106 0183 360110	W4	LDA	M2
00107 0188 0313	W4	OUT	1002
00108 0187 360410	W4	LDA	00H
00109 0188 1E00	W4	CFI	80H
00110 0189 025401		JNZ	00
00111 0180 360810		LDA	M4
00112 0183 2A0410		LHLD	SMPL
00113 0186 20		INR	L
00114 0187 00		MOV	M+0
00115 0188 220410		SHLD	SMPL
00116 018F 210610		LXI	H+WDU
00117 0188 84		INR	M
00118 018F 035401		JMP	00
00119 0110 360410	ITY	LDA	11H
00120 0110 1E00		CFI	80H
00121 0110 030401		JNZ	11
00122 0110 360410		LDA	M4
00123 0110 2A0410		LHLD	1YSU
00124 0110 00		MOV	M+0
00125 0110 20		INR	L
00126 0110 220410		SHLD	1YSU
00127 0110 00		XRA	0
00128 0110 320410		STA	11H
00129 0110 0B01	11	IN	1000
00130 0110 00		RCR	
00131 0110 035401		JNC	00
00132 0110 360410		LDA	1YSU
00133 0110 2A0410		LHLD	1YPI
00134 0110 00		CMP	L
00135 0110 035401		JNZ	10
00136 0110 8E11		MVI	A+11H
00137 0110 0354		OUT	1000
00138 0110 035401		JMP	00
00139 0110 00	11	MOV	A+M
00140 0111 0354		OUT	1000
00141 0113 3E31		MVI	A+31H
00142 0113 0354		OUT	1000
00143 0113 20		INR	L
00144 0113 220410		SHLD	1YPI
00145 0113 035401		JMP	00
00146 0111 360110	001001	LDA	M2
00147 0204 1604		ORI	04H
00148 0203 320110		STA	M2
00149 0206 0313		OUT	1002
00150 0208 210410		LXI	H+PIAF
00151 0204 3603		MVI	M+03H
00152 0200 360110		LDA	0A110
00153 0210 1E06		CFI	06H

00214	0212	C22002	JNZ	MF	#IF NOT, GO TO MF
00215	0215	D319	OUT	IOF8	#OUTPUT CODE
00216	0217	2A2610	LHLD	RMAL	#SF READ ADDRESS
00217	021A	4E	MOV	C,M	#WORD CNTR
00218	021B	3600	MVI	M,0H	#CLEAR FULL FLAG
00219	021D	C32B02	JMP	AU	
00220	0220	D319	OUT	IOF8	#OUTPUT MF CODE
00221	0222	2A2C10	LHLD	RMAL	#MF READ ADDRESS
00222	0225	4E	MOV	C,M	#WORD CNTR
00223	0226	3600	MVI	M,0H	#CLEAR FULL FLAG
00224	0228	EB	XCHG		
00225	0229	0620	MVI	B,20H	#DAV INTO B
00226	022B	DB12	AUI	IN	IOF6
00227	022D	1602	ANI	02H	#IFC?
00228	022F	CA6602	JZ	IFC	
00229	0232	DB12	RIFC	IN	IOF6
00230	0234	0F	RRC		#NRFDHT
00231	0235	E22B02	JNC	AUI	
00232	0238	07	RLC		
00233	0239	07	RLC		
00234	023A	DA2B02	JC	AUI	
00235	023D	78	MOV	A,B	
00236	023E	D31A	OUT	IOF9	#OUTPUT DAV
00237	0240	1C	INR	E	#INCREMENT READ POINTER
00238	0241	DB12	A1	IN	IOF6
00239	0243	07	RLC		#INDAC HI?
00240	0244	124102	JNC	A1	
00241	0247	AF	XRA	A	
00242	0248	D31A	OUT	IOF9	#RESET DAV
00243	024A	B1	ORA	C	#IS THIS THE LAST WORD
00244	024B	CA5E02	JZ	CLR	#IF YES,EXIT
00245	024E	1A	LDAX	D	#DATA INTO ACCUM.
00246	024F	D319	OUT	IOF8	
00247	0251	0B	DCR	C	#DECREMENT WORD COUNTER
00248	0252	C22B02	JNZ	AUI	#MORE DATA?
00249	0255	0624	MVI	B,24H	#PUT EOI.DAV INTO B
00250	0257	3E04	MVI	A,04H	#OUTPUT EOI
00251	0259	D31A	OUT	IOF9	
00252	025B	E32B02	JMP	AUI	
00253	025E	AF	CLR	XRA	A
00254	025F	D319	OUT	IOF8	#CLEAR INTERFACE
00255	0261	D31A	OUT	IOF9	
00256	0263	C37102	JMP	IOF1	#EXIT
00257	0266	AF	IFC	XRA	A
00258	0267	D319	OUT	IOF8	#CLEAR DATA INTERFACE
00259	0269	3E80	MVI	A,80H	#SET IFC FLAG
00260	026B	320D10	STA	IECF	
00261	026E	C39B02	JMP	E48E	
00262	0271	0E0B	INR	C,0H	#RESTARTISH COUNTER
00263	0273	2A2C10	LHLD	RMAL	#POINT TO MF BUFFER
00264	0276	AF	II	XRA	A
00265	0277	B6	ORA	M	#CHECK WORD COUNT
00266	0278	C29302	JNZ	12	#IF ZERO INCREMENT POINTER

0027 027B 10	MOV	A+L	
0028 027C 1620	ADD	20H	
0029 027D 0E	MOV	E+0	
002A 027E 00	DEC	C	#DECREMENT COUNTER
002B 027F 127602	JNZ	I1	#IF NOT ZERO TRY AGAIN
002C 0280 2A2810	LHLD	R0AL	#POINT TO SF BUFFER
002D 0281 0E	XRA	A	
002E 0282 0E	ORA	M	
002F 0283 167102	JZ	100E	#IF WORD COUNT ZERO, RETURN TO 100E
0030 0284 210C10	LXI	H,D011D	
0031 0285 3606	MVI	M+06H	#SET SFID CODE
0032 0286 139B02	JMP	E488	
0033 0287 222110	SHLD	R0AL	#STORE READ ADDRESS
0034 0288 210C10	LXI	H,D011D	
0035 0289 3607	MVI	M+07H	#SET MEID CODE
0036 028A 3A0110	LDA	M2	
0037 028B 1602	ORI	02H	
0038 028C 320110	STA	M2	
0039 028D 0413	OUT	10F2	
003A 028E 210B10	LXI	H+P	
003B 028F 3603	MVI	M+03H	
003C 0290 3E08	MVI	A+08H	
003D 0291 031A	OUT	10F9	#CLEAR INTERFACE
003E 0292 0B17	IN	10F6	#INPUT CONTROL WORD
003F 0293 1620	ANI	20H	#DAV?
0040 0294 1A0302	JZ	A1N	#YES, GO TO A1N
0041 0295 0B17	IN	10F6	
0042 0296 1614	ANI	14H	#A1N & E01?
0043 0297 1A0803	JZ	A1E	#GO ON IF YES
0044 0298 3E8E	MVI	A+8EH	#FDSKQ
0045 0299 031A	OUT	10F9	#OUTPUT RED
0046 029A 13A002	JMP	D0V	#TRY AGAIN
0047 029B 0B17	IN	10F6	#INPUT
0048 029C 1610	ANI	10H	#A1N?
0049 029D 1A0102	JZ	M0P	#TRY AGAIN
004A 029E 3E09	MVI	A+09H	#D0L
004B 029F 031A	OUT	10F9	
004C 02A0 13A002	JMP	D0V	#TRY AGAIN
004D 02A1 0B11	IN	10F6	#INPUT ADDRESS
004E 02A2 1680	ORI	80H	#SET BIT 8-1
004F 02A3 1E02	CFI	0A2H	
0050 02A4 127A02	JNZ	D0	#IF NO, TRY AGAIN
0051 02A5 3E01	MVI	A+01H	#NRD
0052 02A6 031A	OUT	10F9	#OUTPUT RED
0053 02A7 0B12	IN	10F6	
0054 02A8 1620	ANI	20H	
0055 02A9 1A0A02	JZ	M0	
0056 02AA 3E80	MVI	A+80H	
0057 02AB 031A	OUT	10F9	
0058 02AC 0B12	IN	10F6	
0059 02AD 1610	ANI	10H	#A1N?
005A 02AE 1A0E02	JZ	M01	#TRY AGAIN
005B 02AF 0E	XRA	A	

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40

00373	035F	FE90		LFI	90H	#IS WORD 90?
00374	0361	022503		JNZ	S3	
00375	0364	210110		IXI	H+M2	#SET CLOCK
00376	0367	3E01		MVI	A+01H	
00377	0369	86		ORA	M	
00378	036A	320110		STA	M2	
00379	036D	0313		OUT	IOF2	
00380	036F	3EFF		MVI	A+0FEH	
00381	0371	A6		ANA	M	
00382	0372	320110		STA	M2	
00383	0375	0313		OUT	IOF2	
00384	0377	3A3210		LDA	M5	#DECREMENT LOOP COUNTER
00385	037A	40		DEC	A	
00386	037B	323210		STA	M5	
00387	037E	023A03		JNZ	S5	#IF NOT ZERO JUMP
00388	0381	9002		MVI	A+02H	#RESET LOOP COUNTER
00389	0383	323210		STA	M5	
00390	0386	3E19		MVI	A+19H	#UNMASK INTERRUPT
00391	0388	30		SIM		
00392	0389	EB		EI		
00393	038A	037102		JMP	IOF4	#GOTO IDLE
00394	038D	350310	SEI D	LDA	M4	#GET SEID FROM TEMP STORAGE
00395	0390	87		ORA	A	#IS SEID=0?
00396	0391	02B603		JNZ	SE1	#BRANCH TO END IF NOT
00397	0394	352410		LHLD	SBP1	#STORE SE WORD COUNTER IN FIRST LOCATION OF BUFFER
00398	0397	2E00		MVI	L+00H	
00399	0399	350310		LDA	SEC	
00400	039E			MOV	M+A	
00401	039F	2E		XRA	A	#SET SE WORD COUNTER TO 0
00402	039F	350310		STA	SEC	
00403	03A1	2E32		MVI	A+05H	#IS STORE ADDR. 0500H?
00404	03A3	80		CMP	H	
00405	03A4	030003		JNZ	SE2	#BRANCH IF IT IS NOT
00406						#SET STORE ADDR AND POINTER TO 0A00H
00407						#SET READ TO 0500H
00408	03A7	3E0A		MVI	A+0AH	#ELSE SET STORE ADDR AND POINTER TO 0500H
00409						#SET READ TO 0A00H
00410	03A9	323210	SEI	STA	SEBH	
00411	03AB	352410		STA	SEBH	
00412	03AD	2E		XRA	A	
00413	03B0	030003		STA	SEPI	
00414	03B3	2E2610		LHLD	EB01	
00415	03B5	030003	SEI	DEC	RE	#EXIT
00416	03B8	350310	SEI D	LDA	M4	#GET DATA FROM TEMP STORAGE
00417	03BB	2E3410		LHLD	SEPI	#INCREMENT STORAGE POINTER
00418	03BE	2E		INC	I	
00419	03C0	2E3410		LHLD	SEPI	
00420	03C3	2E		ADD	M+A	#STORE DATA
00421	03C4	350310		LDA	SEI	#INCREMENT SUBRANGE WORD COUNTER
00422	03C7	2E		DEC	A	
00423	03C8	030003		STA	SEI	
00424	03CB	035E01		JMP	EB	#EXIT
00425	03CD	350310	SEI	LDA	M4	#GET DATA FROM DATA

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V. PERSONNEL

A list of the engineers who contributed to this investigation is given below:

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Principal Investigator.

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VI. RELATED CONTRACTS AND PUBLICATIONS

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